signals to port 321 (which serves as an auxiliary output for video signals, enabling the signals to be transmitted, e.g., to remote locations outside of the residence).

There are many ways that subprocessor 337 can be implemented to fulfill these functions. Indeed, the closed circuit TV industry provides a large variety of video processing devices that couple video signals, separate video signals, modulate and demodulate signals, and shift signals in frequency. What is shown herein is a method that is preferred in this application, as well as several alternatives.

Demodulators 326a, 326b are frequency demodulators (details are shown only for demodulator 326a) and include a tunable local oscillator and a frequency shifter for converting a selected RF signal to an intermediate frequency (IF) band for demodulation. Master controller 316 selects the RF signal to be demodulated by independently tuning the local oscillators of demodulators 326a, 326b via link 326′. (Link 326′ includes a conductor for each demodulator 326a-326e.) The IF signal is then frequency demodulated to obtain a signal at baseband, which in turn is descrambled (if necessary) to produce the output of the demodulator 326a, 326b.

A local oscillator and a mixer are provided in each AM demodulator 326c-326e (details of demodulator 326e are illustrated) to convert selected cable TV signals applied via port 315 to intermediate frequencies. After the IF signal is filtered, it is envelope detected and descrambled (if necessary) and applied to video switch 328. Master controller 316 selects the cable TV signal (e.g., the channel) that demodulators 326c-326e are to process by independently tuning their local oscillators via link 326′.

Although five demodulators are shown, more or fewer can be used.

Thus, it may be appreciated that controller 316 independently instructs each of demodulators 326a-326e via

link 326' to select and demodulate any of the signals provided by cable 315a or network 302. Each of the five resulting basebanded audio/video signals is then passed to video switch 328. That is, each demodulator 326a-326e selects the signal from one or the other of its two inputs, as determined by controller 316 and communicated over link 326'. A standard demodulation procedure is then applied to this signal, converting the energy within the frequency band corresponding to the "channel" selected for conversion. This "channel" is determined by controller 316 and communicated to the demodulator. The demodulation procedure converts the energy in that channel to a basebanded video signal.

As shown in Fig. 12, switch 328 includes five input ports and six output ports. Each input port receives a video signal and its accompanying audio signal from a demodulator 326a-326e. Likewise, the six output paths of switch 328 each provides the video and audio signals of a television channel. Five of the output ports are connected to graphical processors 329a-329e, respectively; the sixth is coupled to port 321. Video switch 328 switches signals from among the five input ports to any of the six output ports. The assignments of input to output are determined in controller 316 and communicated to switch 328 via communication link 328'. No output port of switch 328 can be provided with more than one signal.

As shown in Fig. 12, switch 328 can provide any of the basebanded signals supplied by demodulators 326a-326e to port 321 for provision to an external device not shown in the drawing. (Under the most general implementation, any of the signals passed to graphical processors 329a-329e, or to modulators 327a-327e, or output by modulators 327a-327e can also be routed to port 321.) An example of specific circuitry to provide these options is not shown.

Port 321 is a coaxial port that is provided on the housing of interface 300 because the selection,

descrambling, and conversion operations performed by processor 312 can be useful for purposes other than transmitting signals across network 302. Specifically, port 321 is useful for provision of video signals to nearby devices at tunable frequencies. For example, one can connect a VCR to port 321 to record signals recovered from network 302. Because this connection can be made via coaxial cable, ordinary video channels can be used, and the VCR can tune the signal directly (VIA its audio/video inputs).

Each of graphical processors 329a-329e can either process its input and pass it a corresponding one of modulators 327a-327e to which it is connected, or it can bypass the processing, sending the video portion of the input signal to such modulator 327a-327e directly. The decision to bypass is determined by controller 316 and communicated to the processor via communication link 329'. The bypass can be implemented by a simple switch (not shown). More or fewer than five graphical processors 329a-329e can be used.

The processing conducted by each of graphical processors 329a-329e alters the signal passing through the processors 329a-329e between switch 328 and one of modulators 327. Two particular alterations or processes are envisioned. One is the overlaying of text on the picture. (An example of this is a VCR or a cable converter that displays the identity of the selected channel by superimposing the channel number on the screen.) The second alteration is the control of the volume of the audio signal. Both of these processes can be applied to basebanded television signals using well known techniques.

Each of the modulators 327a-327e converts the basebanded signal that is applied to it (as is shown, the baseband signal includes unmodulated video information from 0 to 4.2 MHz and an audio sub-carrier that is frequency modulated at 4.5 MHz) to the channel (i.e., frequency band)

and waveform (e.g., AM) used for transmission over internal telephone network 302, as discussed below.

Each modulator 327a-327e (details of only modulator 327e are shown) is an amplitude modulator that includes a fixed-frequency local oscillator (which provides the video carrier frequency), a mixer, and a filter for passing only one sideband (such as the lower sideband) of the mixer output to coupler 331 as the output of modulator 327a-327e. The local oscillators of modulators 327a-327e are preset to different frequencies so that coupler 331 can combine the five outputs onto a single conductive path (such as the red-green pair of telephone wiring) without the signals interfering with each other. For example, the local oscillators of modulators 327a-327e can be set so that modulators 327a-327e respectively produce five AM signals in adjacent 6 MHz bands between 0 and 30 MHz (e.g., frequency range 340b of Fig. 14a). Although five modulators are shown, more or fewer can be used.

Thus, master controller 316 does not control the selection of the modulation frequencies employed by modulators 327a-327e. Of course, if such control is desired, controller 316 can select different modulation frequencies by embodying the local oscillators of modulators 327a-327e as tunable (i.e., "agile") devices, and linking them to controller 316--in much the same manner in which the local oscillators of demodulators 326a-326c are controlled.

The relationship between transmission quality and frequency band and type of modulation provided by modulators 327a-327e is described in U.S. Patent No. 5,010,399 and Part I of this disclosure. Any suitable modulation technique, such as frequency modulation, can be used in place of AM, if desired. The channels provided by modulators 327a-327e must not overlap each other or the frequencies used by any the signals fed onto network 302 by video transmitters 304a-304c ("video in") or the

frequencies used by the control signals applied over network 302 to ("control in") or from ("control out") RF/video processor 312.

Coupler 331 collects all of the modulated signals produced by modulators 327a-327e onto a single conductive path 331a and feeds them to amplifier 332, which increases the energy level of the signals. This increase brings the signals to the energy levels required for transmission across the telephone wiring of the network 302. In general, the levels should be as high as possible without generating radio waves above the legal limits. The amplified signals pass through filter 333 to coupler 325. The filtering impedes amplifier 332 from loading down any of the RF signals on network 302.

Video receivers 303a-303d on network 302 receive the signals generated by modulators 327a-327e, process them, and feed them to the connected devices, i.e., to televisions 305a-305c and VCR 307. The processing performed by each receiver 303a-303d converts each signal to a form tunable by ordinary televisions. Video receivers 303a-303d also detect infrared light patterns representing control signals, convert these patterns to electronic signals (i.e., time-varying voltages), and transmit them onto telephone wiring 302. These functions are fully described in U.S. Patent No. 5,010,399 and Part I of this disclosure.

Video receivers 303a-303d are each embodiments of transceiver 15, shown in Fig. 2 of U.S. Patent No. 5,010,399. (Although component 15, like video receivers 303a-303d, transmits control signals and receives video, it is referred to as a transceiver in U.S. Patent No. 5,010,399, rather than a video receiver.) Several different specific embodiments of transceiver 15, described below, enable it to cooperate with the various systems, also described below, for switching video signals and for assigning frequency bands (i.e. channels) to the various

video signals. These systems determine the tuning options of each of connected televisions 305a-305c, and VCR 307. These embodiments are described below.

Channel Selection when the Video Receivers Tune Only a Single Fixed Channel

Because of switch 328, any of the video signals produced by demodulators 326a-326e can be directed to any one of modulators 327a-327e, which will respond by applying a signal onto network 302 within a fixed channel (i.e., a preset frequency band). This means that each video receiver 303a-303d need only convert signals in the single channel (i.e., frequency band) used by one of modulators 327a-327e to make all video signals from processor 312 available to the television connected to that receiver 303a-303d. This also means that master controller 316 determines which signals are fed to each of televisions 305a-305c (by controlling the selection and operation of demodulators 326a-326e and video switch 328).

When video receivers 303a-303d only receive signals that are transmitted by RF/video processor 312 over a single fixed channel, the design of receivers 303a-303d is simplified. (Several alternative embodiments of receivers 303a-303d that take advantage of this simplification will be described shortly.) Also, channel selection and volume control can be implemented totally within processor 312, so that no settings on the connected television need be disturbed. Because of these simplifications, this system of signal selection and switching is preferred. The functioning of such a system is illustrated by the following example.

Video transmitter 304a (connected to camera 306) transmits its signal using FM encoding in a 12 MHz frequency band between 28 and 40 Mhz, while video transmitter 304c (associated with video game 308) transmits its signal using FM at frequencies between 40 and 52 Mhz. Video transmitter 304b, connected to VCR 307, transmits its signal using FM between the frequencies of 52 and 64 Mhz.

As seen from Fig. 12, each of these signals is applied to both demodulators 326a, 326b, while incoming cable signals (via cable 315a) in the same or different frequency bands are applied to modulators 326c-326e.

Now, let modulator 327a amplitude modulate its input signal, providing that signal within a 6 Mhz AM channel between 16 Mhz and 22 Mhz, and let the video receiver 303a connected to TV 305a be fixed to convert AM signals between those frequencies to either VHF channel 3 or 4. Further, let modulator 327b amplitude modulate its input signal, providing that signal within the channel between 10 Mhz and 16 Mhz, and the video receiver 303b connected to TV 305b be fixed to convert AM signals between 10 and 16 Mhz to either VHF channel 3 or 4. Finally, let modulator 327c amplitude modulate its input signal, providing that signal within the channel between 22 Mhz and 28 Mhz, and let video receiver 303d connected to VCR 307 be fixed to convert AM signals between 22 and 28 Mhz to either VHF channel 3 or 4.

Under this arrangement, switch 328 (as controlled by controller 316) can independently supply televisions 305a-305b and VCR 307 with any of the signals on network 302 or supplied through cable port 315. For example, to direct the signal from video game 308 to TV 304b, modulator 326a demodulates the 40-52 Mhz FM signal (from transmitter 304c), and controller 316 directs switch 328 to apply that signal to modulator 327b. As described above, modulator 327b will transmit the game signal using AM between 10 and 16 Mhz. As a result, video receiver 303b converts that signal and supplies it to TV 304 at VHF channel 3 or 4.

Several designs are now discussed for video receivers 303a-303d that cooperate with the system for communication with RF/video processor 312 described immediately above. The requirements of that system are that a video receiver:

- can connect to telephone network 302 without disturbing telephone communications,

- can receive a video signal from telephone network 302 within a particular frequency band, and convert that signal to one that can be tuned by ordinary televisions,

- can detect infrared control signals, convert them to electrical signals at frequencies above voiceband, and transmit them onto telephone wiring 302.

All of these requirements are met by transceiver 15, shown in Fig. 2 of U.S. Patent No. 5,010,399. Thus, video receivers 303a-303d are all embodiments of that device.

Video receiver 303a is shown in Fig. 13 of this application. Video signals on network 302 present to coupling network 342, which routes them to RF converter 345. That component converts the video signal from the frequency at which it is received to a signal that can be fed to the connected television 305a. IR sensitive diode 343 detects infrared signals (e.g., from hand held remote control device 307'), converts them to voltage variations or other electrical signals, and passes the electrical signals through coupling network 342 and onto network 302. All the elements shown in Fig. 13 are identical to those of transceiver 15 of U.S. Patent No. 5,010,399. The variations in receiver 303a disclosed in the following paragraphs are each expressed as an alternative embodiment of RF converter 345.

One embodiment of RF converter 345 is shown in Fig. 15A. RF converter 345 includes a demodulator/modulator pair 346, 349. Incoming, modulated video signals from coupling network 342 (Fig. 13) are applied to demodulator 346, which converts the modulated signals to baseband using well known procedures. The demodulated signal is passed to modulator 349, which converts the signal to a channel tunable by ordinary televisions (such as VHF channel 3 or 4).

As described in U.S. Patent No. 5,010,399, there is an advantage in allowing the user to choose to provide the received video signal at one of two adjacent low-VHF

channels (e.g., VHF channel 3 or VHF channel 4). This allows the user to avoid interference of the output signal with local television broadcast sources. Modulation channel control 348 is provided for that purpose. Modulator 349 is not required, of course, when video receiver 303a connects to the baseband port of a television.

In the example described above, video receivers 303a-303d are each assigned a different channel at which to receive a signal. Manufacture and distribution of these receivers is more economical, however, if they are all designed identically. One solution is to provide these receivers with the ability to be set to any one of the channels transmitted by processor 312. This solution is provided by demodulation channel control 347, as described in the following paragraph.

Some demodulation devices, known as agile demodulators, can demodulate signals of varying carrier frequencies. That is, these demodulators can vary their demodulating frequency. A cable converter box that presents its output in basebanded form is one example of such a device. Demodulation channel control 347 provides this adjustment capability to demodulator 346, using known techniques. Demodulator 346 can be equipped with electronics to create any of the local oscillators necessary to demodulate the signals it will input. In this case, demodulation channel control 347 can simply communicate to demodulator 346 the identity or frequency of the l.o. (local oscillator) to be used. Alternatively, control 347 can actually supply the l.o. to demodulator 346.

Part I of this disclosure describes some of the advantages of using FM for encoding video signals. It will be appreciated that demodulator 346 can embody well known FM demodulation techniques (if such an arrangement is desired, and if processor 312 and/or video transmitters 304

provide FM video signals), as well as AM techniques.

Fig. 15B shows an alternative embodiment of RF converter 345′ that does not include demodulation but has automatic gain control (AGC). Signals are passed from coupling network 342 (Fig. 13) to gain control 351 which is part of AGC (automatic gain control) circuitry 350. Gain control 351 adjusts the level of the signal. This adjustment is made according to a signal set by integrator/comparator 352.

Integrator/comparator 352 creates its signal by measuring the signal energy output by gain control 351 and comparing it to a signal whose level is known to be approximately equal to the desired output level of gain control 351. Deviations of the measured level from the desired level are indications of the amount of adjustment required on the part of gain control 351. These deviations form the signal sent by integrator/comparator 352 to gain control 351.

Filtering may be required by integrator/comparator 352 to ensure that the energy it measures derives mainly from energy within the channel of interest. This filtering is performed by filter 356, which receives the output of gain control 351 and feeds integrator/comparator 352.

The signal produced by AGC 350 is sent to mixer 353, which is part of block converter 355. Mixer 353 multiplies the input signal by the output (fundamental) frequency of oscillator 354a or oscillator 354b. The choice between these oscillators is determined by switch 353a (e.g., a manual slide switch similar to the "channel 3/4" switch commonly found on VCRs). Multiplication by the selected oscillator frequency shifts the signal up in frequency by an amount equal to the frequency of the oscillator. (The filtering used to remove one of the two sidebands is not shown.)

The result of block converter 355 is conversion of the signal applied to RF converter 345′ to a higher

channel. For example, if the frequency of oscillator 354a is set to 182.8 Mhz, and the input signal is AM modulated with a picture carrier of 22.45 Mhz, when oscillator 354a is selected by switch 353a the output signal will have a picture carrier of 205.25 Mhz, which corresponds to VHF 12.

Block converter 355 includes two oscillators 354a, 354b to help ensure that the signal can be provided to the connected television at a channel that is unused by local broadcasting. As explained in U.S. Patent No. 5,010,399, the U.S. FCC does not allow broadcasting at both of two adjacent channels within the same locality. Thus, using the above example, if the frequency of oscillator 354a is 182.8 Mhz, and the frequency of oscillator 354b is 188.8 Mhz, the output signal can be provided with a picture carrier of 205.25 or 211.25, i.e. VHF channel 12 or 13.

Note that because RF converter 345′ does not remodulate the signals applied to it, it should not be used when the applied signals are FM because typical televisions are constructed to receive AM rather than FM signals.

In addition to the two embodiments shown herein, U.S. Patent No. 5,010,399 describes several embodiments of transceiver 15 that only detect signals in a single video channel. Because they provide the functions listed above, each of these can suffice for video receivers 303a-303d.

<u>Simultaneously Providing Multiple Video Signals to Televisions</u>

A second system of allocating channels that has a number of advantages, described below, is possible when all, or most, video signals are retransmitted via RF/video processor 312 (i.e., when all or most video receivers 303a-303d receive their video signals from transmitters 304a-304c through processor 312, rather than directly from transmitters 304a-304c). This system takes advantage of the fact that all of the multiple video signals simultaneously fed by interface 300 to network 302 will take the same path in transmitting to a particular television. Among other advantages, this feature allows

the video receivers to provide automatic gain control less expensively. (One advantage is that users may appreciate having several video signals supplied at different channels simultaneously, even though this does not really expand the viewing options.) This system is described in the following paragraphs.

Referring to Fig. 14A, three ranges 340a, 340b, 340c of channels are defined for transmission of signals by RF/video processor 312 and the connected video transmitters. Range 340a includes the five low VHF channels 2 through 6 (in the frequency band of 54 MHz - 88 MHz). Range 340b consists of the frequency band below 30 Mhz. These frequencies are called sub-tunable because they are below 54 Mhz (the lower end of the VHF range). Range 340c is divided into two parts; the first part spans the 24 Mhz between 30 Mhz and 54 Mhz, and the second part covers the 24 Mhz between 108 Mhz and 132 Mhz.

In this system of channel allocation, the signals transmitted from RF/video processor 312 to video receivers 303a-303d (i.e., "video out") use adjacent channels in range 340b. As described in U.S. Patent No. 5,010,399 and Part I of this disclosure, radiation restrictions imposed by the U.S. FCC relax considerably below 30 Mhz, making that band a good candidate for transmission. In a preferred arrangement, five adjacent 6 Mhz wide AM channels cover this range, with the sound and video information organized according to the NTSC standard. (That standard dictates that the picture carrier be 1.25 Mhz above the low end, and the sound carrier be .25 Mhz below the high end of the channel.) The lowest channel will include frequencies between 0 and 6 Mhz, the second channel will span between 6 and 12 Mhz, etc. The picture carriers of these channels will be at 1.25, 7.25, 13.25, 19.25, and 25.25 Mhz. The electronics will filter out the video energy below 1 Mhz to prevent interference with voiceband communications. The information content at these frequencies is redundant and

of minimal importance, as described in U.S. Patent No. 5,010,399.

One advantage of this system is that the maximum number of adjacent channels (i.e., five) are provided below 30 Mhz (in range 340b). To fully utilize this system, then, at least five of modulators 327 are provided, with each modulator 327a-327e being assigned a different 6 Mhz band within range 340b.

Referring to Fig. 14B, an alternative allocation of channels in the second range 340b' is presented, because some of the channels in range 340b (Fig. 14A) straddle amateur radio bands that can provide broadcast interference, including the citizen's band at 27 Mhz. Under this alternative, four adjacent 6 Mhz bands are provided, beginning at 3.2 Mhz. (As shown in Fig 4B, a gap appears between adjacent channels. This gap simply indicates that there is unused spectral space between the channels. It does not mean that the channels are not adjacent - they are.) The location of the picture carriers of the four channels 340b' follows the NTSC standard, placing them at 4.45, 10.45, 16.45, and 22.45 Mhz, respectively. This will strategically place the 15 meter amateur radio band between the third and fourth channels and will place the fourth channel under the citizen's radio band at 27 Mhz. The first two channels are low enough in frequency to have sufficient immunity from broadcast interference. A disadvantage is that four channels are provided instead of the five that range 340b provides.

This disadvantage can be eliminated if a 6 Mhz channel is added adjacent and above the uppermost channel in range 340b' (i.e., the channel that has a picture carrier at 22.45 Mhz). The picture carrier of this channel would be at 28.45 Mhz. Although some of the energy of this channel will be concentrated above 30 Mhz, most of the energy will concentrate below. Thus, there is a possibility that, as a practical matter, the channel will

enjoy the regulatory benefits enjoyed by signals whose energy is concentrated entirely below 30 Mhz. (To avoid overlap with signals in range 340c, the lower two channels in that range could be placed at 34-44 MHz and 44-54 MHz, respectively. Of course, this would reduce their bandwidths by 2 MHz, decreasing the immunity of FM signals in those channels to interference. Another alternative is to not use the 30-42 MHz band in range 340c.)

Range 340a is also known as the low-VHF range. As described in U.S. Patent No. 5,010,399 and Part I of this disclosure, there are always at least two channels in any locality that are not used for local broadcasting in this range. Most commonly, these will be VHF channel 3 and VHF channel 6. The primary use for range 340a is to provide channels for direct transmission between the video transmitters 304a-304c and the video receivers 303a-303d (i.e., video signals transmitted over network 302 in range 340a are not retransmitted to receivers 303a-303d by processor 312).

The primary use for range 340c is for transmission between the video transmitters 304a-304c and RF/video processor 312. It is recommended that two 12 Mhz adjacent FM channels transmit in each of the 24 MHz bands (30 MHz-54 MHz and 108 MHz-132 MHz) in range 340c. FM is recommended because its lower minimum SNR (signal-to-noise ratio) requirements may be needed to compensate for interference. Interference can be a problem because F.C.C. rules limit radiation, and thus signal power, more strictly above 30 Mhz, and because significant interference can occur within range 340c.

The 108 Mhz - 132 Mhz band is used because it represents the first opportunity, above range 340a (which ends at 88 Mhz), to find 12 Mhz wide channels that are not likely to encounter significant interference from broadcast sources. (The band between 88 Mhz and 108 Mhz has a high potential for interference because it is used by commercial

FM radio stations. Television broadcasting does not begin again until 176 Mhz, which is the low end of VHF channel 7.)

The 12 Mhz bandwidth is chosen because it is approximately the width used by inexpensive commercial FM video communication equipment. This is somewhat arbitrary. Indeed, wider bandwidths may be necessary to reduce the minimum SNR required at the input to the video receivers, and to provide sufficient interference rejection. This is especially true at the higher range (108-132 Mhz) where signal attenuation and signal radiation are higher.

To completely specify how signals are transmitted under this system, one must assign every channel in the three frequency ranges 340a, 340b (or 340b′), and 340c to either: (1) video transmitters 304a-304c, or (2) modulators 327a-327e. (To avoid interference, the channels used by the modulators 327a-327e must not overlap those used by the video transmitters.) The preferred system is for each of video transmitters 304a-304c to transmit its signal for retransmission by processor 312 at a different one of the four FM channels in range 340c, and for modulators 327a-327e to transmit at the five adjacent AM channels in range 340b. If extra modulators are provided within processor 312, they can transmit at unused channels in range 340a.

Referring to Fig. 12, each modulator 327a-327e is assigned to perform amplitude modulation within a single frequency band in range 340b, and is set to produce its output signal at the same energy level as all other modulators 327a-327e. These outputs are combined by coupler 331, resulting in a combined signal that includes energy expressed at all of the frequencies within range 340b. This combined signal is fed to amplifier 332, which imparts a gain that is equal at all frequencies of range 340b. This leaves all signals at the same level upon output.

The gain of amplifier 332 is set so that the video signal with the highest frequency (e.g., the signal in range 340b that has a picture carrier at 25.25 Mhz) generates electromagnetic radiation slightly below present F.C.C. limits. As a result, the gain setting defines the maximum level of the video signals that reach video receivers 303a-303a.

Amplifier 332 imparts the same gain to the four other AM signals in range 340b with picture carriers below 25.25 Mhz. Because electromagnetic radiation decreases with frequency, the radiation generated by these signals will also be within the legal limits. Furthermore, because all signals traverse the same path over network 302, those at lower frequencies, which suffer less attenuation per unit length, will be applied to video receivers 303a-303d at higher levels. Thus, if the highest frequency signal meets the minimum level required for quality video, the others also will. If the level of the highest frequency channel (i.e., 25.25 MHz) is not sufficient to reliably communicate quality video, it should be deleted from the allocation system, and the gain of amplifier 332 should be increased so that EM radiation from the signal next highest in frequency falls just below the minimum.

Upon recovery from network 302 of the video signals transmitted by modulators 327a-327e, each receiver 303a-303d processes the signals and simultaneously feeds all of them to televisions 305a-305c and VCR 307, respectively. In one embodiment, video receivers 303a-303d are restricted to processing only video signals fed to telephone wiring 302 by RF/video transmitter 312 within range 340b. This provides certain advantages, described below. In another, more general embodiment, each of video receivers 303a-303d can also directly receive (i.e., without retransmission by transmitter 312) all of the signals fed by transmitters 304a-304c in range 340a. That is, they can receive signals in range 340a.

We now describe several alternative designs for video receivers 303a-303d that process only video signals fed to telephone wiring 302 by RF/video transmitter 312. Receivers built according to these designs meet the requirement that they receive all signals within range 340b and provide all of those signals in a form that can be tuned by ordinary televisions and at levels within legal limits. They must also connect to telephone network 302 without disturbing telephone communications, detect infrared control signals, convert them to voltage variations at frequencies above voiceband, and transmit them onto the wiring. Any video receiver meeting these requirements will also fit the description of transceiver 15 of U.S. Patent No. 5,010,399. Video receiver 303a, shown in Fig. 13, was described earlier and it is identical to transceiver 15. Receiver 303a includes RF converter 345, which is labelled "RF converter 19" in U.S. Patent No. 5,010,399. All of the variations in the receiver disclosed in the following paragraphs will be confined to specific embodiments of RF converter 345. Video receiver 303a, shown in Fig. 13, was described earlier, and follows the design of transceiver 15. The variations in the receivers design of transceiver 15. The variations in the receivers disclosed in the following paragraphs will all be confined to specific embodiments of RF converter 345.

Figure 15b shows RF converter 345'. Use of that converter by video processor 303a to receive AM NTSC video signals was described above. The design of converter 345' makes it well suited, however, for use when video receiver 303a receives signals only from processor 312. Specifically, RF converter 345' can convert all of the channels in range 340b to tunable channels with a single block conversion. This is done as follows.

Incoming signals from coupling network 342 (Fig. 13) are applied to automatic gain control (AGC) 350, which automatically adjusts the signal level to be within a range acceptable to most televisions. As described above,

integrator/comparator 352 measures the output of gain control 351 and subtracts that level from the input signal.

Circuitry 350 performs AGC by applying the same gain to all the video signals passing from coupling network 342, and sets the gain so that the level of the signal with the lowest frequency is just below the maximum permitted level (described above). If, for example, the lowest frequency signal transmitted by processor 312 is one with a picture carrier whose frequency is 7.25 Mhz in range 340b (Fig. 14a) AGC 350 sets the gain so that the level of that signal is slightly below 15dB mV. That value is the limit on the conducted output that can be furnished to a TV set by the FCC in the U.S. Because signals transmitted at the higher frequencies suffer greater attenuation as they transmit, their levels will also fall below this limit.

To set the gain in this manner, AGC filter 356 confines the input to integrator/comparator 352 to a narrow band centered at 7.25 Mhz, and integrator/comparator 352 compares this signal to a reference level of 15dB mV.

A potential problem can arise if the difference between the levels at the lowest and highest frequencies in the transmission frequency band used by RF/video processor 312 is greater than 15dB mV. In that event, when the level of the lowest frequency signal in the band is set to 15dB mV, the level at the highest frequency signal in the band falls below 0dB, the level below which video quality will noticeably degrade. One solution is to apply a sloped gain that is higher at higher frequencies. For example, assume that due to higher attenuation at higher frequencies, the signal sent by RF/video processor 312 with a picture carrier at 25.25 Mhz is applied to AGC 350 with a level of 10 dB mV, and the video signal sent by processor with a picture carrier at 7.25 Mhz is applied to AGC 350 at a level of 30 dB mV. If gain control 351 is set to attenuate signals at 25.25 Mhz by 10dB, to attenuate signals at 7.25 Mhz by 15dB, and to vary linearly between those limits,

then both signals will be below the legal limit, yet will also be equal to or above the level of minimum quality.

Ideally, a fixed slope can be found that will be adequate for all residences. Even if no such slope exists, providing a variable slope, set manually or automatically, is far less complex than performing an AGC on each individual channel. Gain control 351 can be designed to provide a gain with a fixed slope or variable slope using known means.

When no legal limits apply, it is preferred that AGC 350 set the level of the highest frequency signal to 0dB re mV. This level is just above the minimum required for quality video. Because the lower frequency signals attenuate less, they will also be above the minimum.

Signals produced by AGC 350 are applied to block converter 355, which imparts a single upward shift in frequency to all of its input signals. The amount of this upward shift is determined by the local oscillator. This oscillator is selected by switch 353a, which chooses between oscillator 354a or 354b. The shift is such that each signal in the output falls within a channel tunable by ordinary televisions. For example, if oscillator 354a is at 186 Mhz and is selected by switch 353a, an AM signal with picture carrier at 25.25 Mhz would be shifted to VHF channel 13 (at 211.25 Mhz). A little thought reveals that block converter 355 would shift the other four signals in range 340b to VHF channels 9 through 12, respectively.

To preserve the adjustment of AGC circuitry 350, block converter 355 does not change the energy level of the signals that are applied to it. (Alternatively, gain control 351 can adjust its gain to reflect an anticipated gain, or loss, in block converter 355.) It is also feasible to permute AGC 350 and block converter 355, performing gain control after conversion.

Switch 353a allows the user to vary the frequency shift of block converter 355 so that the user can more

easily find five consecutive channels that are unused for broadcasting. Referring to Fig. 15B, if the frequency of oscillator 354a is set to 186 Mhz and that of oscillator 354b is set to 180 Mhz, switch 353a allows the user to choose an upshift to VHF channels 8-12 in place of channels 9-13, simply by selecting oscillator 354b. This has a significant advantage over a fixed upshift. Specifically, it enables the user, in some situations, to switch to a band where more of the channels are empty, i.e. not used for local broadcasting. If a third oscillator is provided at 174 Mhz (together with a three position switch 353a), the option to select VHF channels 7-11 can be added. Another alternative is to set oscillators 354a, 354b to frequencies that provide shifts to ranges in the UHF TV band (it may be easier to find five adjacent UHF channels that are not used for broadcasting).

In the procedure described above, RF/video processor 312 transmits signals at adjacent 6 Mhz channels below 30 Mhz in range 340b, and video receivers 303a-303d convert these signals to tunable channels using a single block conversion 355. No other video signals are produced by the video receivers.

A more general embodiment is to have at least one video transmitter 304a-304c feed its signal onto network 302 within a channel in range 340a (i.e. channels between VHF 2 and VHF 6) and to allow video receivers 303a-303d to receive such signals directly, in addition to receiving and processing signals in range 340b as described above. Direct transmission of a signal in this manner has an advantage because it requires the use of only one of the channels available on network 302. This is in contrast to the retransmission technique that requires a signal to use two channels: one channel during transmission to processor 312, and another during transmission to video receivers 303a-303d.

Under this alternative, however, adjusting the

signal levels within video receivers 303a-303d is more complicated, because different signals are typically transmitted over different path lengths of telephone wiring 302. This means that the identity of the strongest signal will not be known unless all signals are measured, and there will not, in general, be a monotonic relationship between signal level and increasing frequency. (By contrast, when all signals are transmitted at the same energy level from the same point -- such as processor 312 -- the signal lowest in frequency will always be received with the highest level.) It also opens up the possibility that the signals will be received by video receivers 303a-303d at levels differing by much more than 15dB mV. As shown above, this means that if a single gain is applied to set the highest energy signal at the legal limit, the lowest energy signal will fall below the minimum required level.

One possible (but relatively complex) solution is to provide an AGC for each channel. A simpler solution is to have gain control 351 (Fig. 15B) adjust gain so that the total energy of all the signals is set at 15dB mV, or whatever the legal limit is. AGC 350 will respond in this manner if filter 356 is broadened to allow passage of the frequencies of all the signals that will be provided to the connected television. For example, assume signals reach a video receiver 303a over three different channels with levels of 25dB mV, 20dB mV, and 16dB mV. The total energy measured by integrator/comparator 352 in this example will be 30.5 dB mV. Thus, gain control 352 will apply a gain of -15.5 dB, leaving the lowest-level signal at 0.5 db mV, still above the 0 dB mV minimum. Fig. 15C illustrates another alternative RF converter 345'' that embodies an approach to the technique just described, which is more likely to provide each signal above the minimum and below the legal maximum level. Converter 345'' performs separate gain adjustments on the low-VHF signals (i.e., the signals

in band 340a) and the signals below 30 Mhz (in range 340b). Video signals emerging from coupling network 342 (Fig. 13) are applied to splitter 359 (which includes a pair of bandpass filters), which passes signals below 30 Mhz to AGC 350 and block converter 355 (these devices, in turn, process the signals in range 340b in the same manner as that described above). Splitter 359 directs signals in range 340a (the low-VHF channels) to AGC 357, which imparts a gain selected so that the total energy of the signals in range 340a meets a fixed limit. The output of AGC 357 passes to coupler 358, where it is combined with the output of block converter 355. All signals produced by coupler 358 are applied to television receiver 305a.

By dividing the signals in this manner and applying separate AGC to each, the difference between the highest and lowest energy signals in each range 340a, 340b is likely to be less, because there are fewer signals in each group and the gain control is tailored to each frequency range. For example, assume processor 312 transmits 6 Mhz wide NTSC signals with picture carriers of 7.25 Mhz, 13.25 Mhz, and 19.25 Mhz that are received by video receiver 303a with levels of 25dB mV, 20dB mV, and 16dB mV, respectively. Further, assume video transmitters 304a and 304b apply signals at VHF 3 and VHF 6, respectively, to network 302 and that each signal is received at video receiver 303a at a level of 10dB mV. AGC 350 applies a gain of -15dB to the lower frequency signals, as described above (which reduces the levels of the three video signals in range 340b to 10dB mV, 5dB mV, and 1dB mV, respectively). AGC 357, meanwhile, measures a level of 16dB mV in the low-VHF range, and responds by imparting a "gain" of -1dB, leaving the two signals at 9dB mV.

RF converter 345'' of Fig. 15C can also be used if processor 312 (rather than video transmitters 304a-304c) uses the low-VHF channels. For example, let video transmitters 304a and 304b each transmit a signal to

processor 312 using channels in range 340c, and let processor 312 transmit signals at VHF 3 and VHF 6 (in range 340a) in addition to the channels in range 340b. In this situation, all signals reach video receiver 303a by following the same transmission path. Thus, the signals attenuate in a predictable manner (i.e., the higher frequency signals attenuate more than signals at lower frequencies). This means that separating the channels according to high and low frequencies (e.g., ranges 340b and 340a), as is accomplished in Fig. 15C, is likely to create two groups of signals that have similar levels. Thus, AGC 350 and AGC 357 are even more likely to provide all of their output signals at levels above the minimum required for quality video, and below the limit imposed by regulations.

Control Signal Processing (Fig. 16)

Users who view a television signal (such as at TV 305a) from a remote video source (e.g., a VCR 307 located in another room in the residence) can exercise control over that source using the control signal communication system described in U.S. Patent No. 5,010,399 and Part I of this disclosure. In the typical arrangement, described therein, a video receiver (e.g., receiver 303a) detects the infrared signals (produced by hand-held control device 307') intended to control VCR 307. Receiver 303a converts the infrared signals to voltage variations at frequencies above voiceband, and transmits them across telephone wiring 302. The video transmitter connected to the video source (such as transmitter 304b for VCR 307) detects the electrical version of the control signal on network 302, reconverts it to baseband, and recreates the infrared light patterns with enough strength to excite VCR 307.

As explained in U.S. Patent No. 5,010,399, control signals from infrared transmitters have less information content than video signals and can, therefore, be accurately received at a much lower SNR within any given

bandwidth. Thus, the choice of a transmission band for these signals is somewhat arbitrary. Because of how the video signals are distributed, however, the only available frequency bands below 132 Mhz are the band between 72-76 Mhz and the band above voiceband and below approximately 1 Mhz. (The limit of 1 Mhz is approximately where the lower vestigial sideband of the first channel in range 340b can be cut off.)

Communication between video receivers and video transmitters does not, however, provide a system for communication between a viewer and RF/video processor 312. Such communication is desired to allow a viewer to select a particular signal from incoming cable TV signals at port 315. Interface 300 includes two methods of providing such communication. One method, described in this section, is implemented by control signal processor 330, which is part of processor 312. That component receives control signals sent over network 302, and feeds them to master controller 316. The other method, described in the next section, is implemented by low frequency processor 311 (Fig. 11). That component detects DTMF signals, allowing viewers to send signals to controller 316 using a telephone.

Control signals from infrared transmitter 307' are received and interpreted by processor 312 in the following manner. The signals are detected by video receiver 303a, converted to voltage variations, used to modulate a carrier at a frequency above voiceband, and fed to network 302. The electrical control signals transmit across the wiring of network 302 and are applied to processor 312 via high-pass filter 313 (Fig. 12). In processor 312, the control signals ("control in") pass through coupler 325 and bandpass filter 334 to control signal processor 330.

Referring also to Fig. 16, demodulator 339 demodulates and filters the control signals recreating the basebanded, electrical version of the original infrared light pattern. These filtering and conversion processes

are described in greater detail below. The baseband electrical version of the control signals are digitized by digitizer 324 so they can be transmitted to and interpreted by the digital circuitry of controller 316. Means to accomplish this digitization in a meaningful manner are used in common universal infrared control transmitters. A description of one technique for accomplishing this digitization is described below.

Transmitter 307′ communicates with VCR 307 using eight bit sequences, i.e., every instruction is associated with such a sequence. A "one" bit is transmitted when transmitter 307′ generates rapid IR pulses (e.g., 40,000 pulses per second) over an interval of 0.001 seconds. A "zero" bit is indicated by a lack of pulses during the interval. Common infrared remote control devices operate in a similar manner, only with varying pulse rates and interval lengths.

The result of the demodulation of the electrical version of this signal within processor 330 is a waveform with energy that is spread, approximately, over frequencies between 1 Khz and 120 Khz. (This frequency range assumes that the highest frequency is the third harmonic of the 40 Khz pulse rate. The lowest frequency is approximately 1KHz, which is the recurrence rate of the bit pattern.) Digitizer 324 samples this waveform at a rate higher than 240 Khz (the Nyquist frequency) and then rectifies and averages to produce a bilevel signal. This signal is then sampled at the .001 second interval, recreating the original series of "zeros" and "ones." This digital bitstream is transmitted to controller 316 over communication link 330′.

Two pieces of information are communicated between the remote sites (e.g. receiver 303a) and processor 312. One piece of information determines the action to be taken, e.g., selecting a new video signal. The other piece of information indicates which of modulators 327a-327e is to

respond, e.g., transmit the newly-selected signal. For example, assume that modulator 327a in RF/video processor 312 supplies its video signal within a 6 Mhz NTSC channel whose center frequency is at 7.25 Mhz, and that RF converter 345 (Fig. 13) in video receiver 303a converts the energy in that channel to VHF channel 12 and provides it to television 305a. If the viewer wants to view a different signal (e.g. a different cable channel), the signal sent by that viewer (using remote control 307') must include both the identity of the new signal and an indication that the new signal is to be transmitted from the modulator that uses the 7.25 Mhz channel.

One method of communicating the identity of the particular modulator 327 that provides its signal within the channel is to encode that information in the signal issued by the transmitter. For example, the first three digits of the eight bit pattern described above can indicate the modulator identity by the following simple association:

000 - modulator 327a
001 - modulator 327b
010 - modulator 327c
011 - modulator 327d
100 - modulator 327e

The remaining 5 bits can be used to identify the new channel.

A preferred method is for each video receiver 303 to indicate the identity of the associated modulator 327 by transmitting a simple sinusoid at a specified frequency at the same time it transmits the control signal. Under this system, processor 312 identifies the correct one of modulators 327 by detecting this sinusoid. For example, each of video receivers 303 can transmit its control signal between 72-76 Mhz in the ordinary manner, and simultaneously transmit a sinusoid at a different frequency.

The following table illustrates an example of a set of associations that can be used:

| Modulator | Video Receiver | Frequency | Signal |
|---|---|---|---|
| modulator 327a | 303a | 0-6 Mhz | .5 Mhz sinusoid |
| modulator 327b | 303b | 6-12 Mhz | .6 Mhz sinusoid |
| modulator 327c | 303c | 12-18 Mhz | .7 Mhz sinusoid |
| modulator 327d | 303d | 18-24 Mhz | .8 Mhz sinusoid |
| modulator 327e | 303e | 24-30 Mhz | .9 Mhz sinusoid |

With this arrangement, for example, modulator 327b transmits its video signal amplitude modulated between the frequencies of 6-12 Mhz, and video receiver 303b receives video signals in the same channel. Video receiver 303b also transmits the control signals it detects within the band from 72-76 Mhz, and simultaneously transmits a sinusoid at .6 Mhz. (Modification of transceivers, such as video receivers 303, to simultaneously transmit extra signals is described in Part I of this disclosure.)

Demodulator 339 detects the sinusoids and the control signals as follows. Referring to Fig. 16A, signals between .5-1 Mhz and 72-76 Mhz pass through bandpass filter 334 and transmit to demodulator 339. These signals are amplified by amplifier 373 and are split six ways by splitter 374, feeding each of the six filters 375a-375f. Filter 375f passes signals between 72-76 Mhz, thus passing the control signal. The output of that filter is passed to demodulation circuitry 377. Using technology described in U.S. Patent No. 5,010,399 and Part I of this disclosure, circuitry 377 basebands the control signal, passing the result to digitizer 324 (Fig. 16) which responds by creating a digital bitstream, as described above.

At the same time as the control signals are processed, the outputs of each of the other filters 375a-375e feed detector 376. Detector 376 identifies which of these filters is passing harmonic energy, and provides that information to digitizer 324. Digitizer 324 transmits the bitstream and the identification information to master controller 316. All of this processing can be accomplished using commonly known means.

This system is preferred because it makes it much

easier to coordinate ordinary remote control transmitters with master controller 316. This is because the identity of the video is provided automatically -- the viewer does not have to train controller 316 to recognize a special sequence, and does not have to deliver such a sequence with each signal. This allows one to use, for example, a single transmitter in different rooms (i.e. with different one of video receivers 303) without being concerned about the identity of the video receiver 303 in each room.

Note that communication of infrared signals from video receivers 303 to video transmitters 304 is not affected. This is because video transmitters 304 are not equipped to detect the new sinusoids. Thus, using the above example, video transmitters 304 will demodulate control signals in the frequency band between 72-76 Mhz, but will ignore the sinusoids between .5 - 1 Mhz.

Low Frequency Signal Processor (Fig. 17)

In the above system, users communicate with processor 312 from remote sites (e.g., receivers 303a-303d) through infrared transmitters such as IR remote device 307'. To allow users to communicate with processor 312 through touch tone (DTMF) telephone signals rather than infrared signals, processor 311 is connected to telephone network 302 (via low pass filter 314, Fig. 11) to detect predetermined sequences of touch tones entered by the user on any telephone 310a-310c connected to network 302. This is done in the following manner.

Referring to Figs. 11 and 17, low frequency signal processor 311 is interposed between internal residential telephone network 302 and public telephone network 301. Internal to low frequency signal processor 311, ring detector 363 is connected across the red-green pair with a high impedance so that it will not disturb communications, and measures variations in line voltage using known circuitry. Ring detector 363 detects rings by triggering when a high current is detected on the line, or when a high

concentration of energy at the ringing frequencies is detected. Touch tone detector 364 (connected across the red-green pair of the incoming telephone line from internal network 302) measures voltage on the line without disturbing communications. Using known circuitry, touch tone detector 364 examines these voltage variations for DTMF signals. Both detectors 363 and 364 control switch/power supply 366, and indicate to that device when a touch tone or a ring is detected.

These elements of processor 311 facilitate touch tone communication between a user and controller 316. For example, using any telephone on network 302 (such as telephone 310a), a user enters a "prefix," which consists of a selected sequence of touch tones, which is detected and recognized by touch tone detector 364. Detector 364 responds by sending a control signal to switch/power supply 366, causing it to temporarily break the connection between public network 301 and residential network 302. This prevents succeeding touch tones from being transmitted over public telephone network 301 (e.g., to the central exchange). Simultaneously, switch/power supply 366 imposes a 50V DC signal across the red-green wire pair from network 302 to sustain power to telephones 310a-310c and allow them to deliver further touch tones and conduct other operations. If detector 363 detects a ring during the interval in which the connection between networks 301, 302 is interrupted, detector 363 sends an indication to switch/power supply 366 to cause it to reestablish the connection to public network 301, allowing the user to answer the call. When touch tone detector 364 does not detect a tone over a preselected time interval, it sends a similar signal to switch/power supply 366 to reconnect public and private telephone networks 301, 302.

After detector 364 senses the prefix, it communicates succeeding DTMF signals that it receives to controller 316' over link 311'. Detector 364 terminates

the touch tone stream at the time that switch/power supply 366 reconnects networks 301, 302. (Ring detector 363 may, but need not, send its ring detections to controller 316.) The detected DTMF tones sent to controller 316 comprise the commands from the user that are arranged according to any suitable protocol. For example, to select a cable TV channel, the first digit entered by the user after the prefix can designate which of demodulators 326c-326e is to be used, with the TV channel to be selected designated by the following two digits entered by the user.

In addition, two-way communication between controller 316 and modem 317 is provided over link 311′. Communications over link 311′ can be conducted using ordinary digital techniques. As a result, controller 316 can direct modem 317 to send digital information (applied to modem 317 via link 311′) to a remote location over public telephone network 301.

<u>A System for Communication Between Users and Master Controller 316</u>

To provide numerous communication and control functions, interface 300 has two additional capabilities. The first is the ability to "learn" control signals (i.e., commands) fed to network 302, particularly control signals from infrared transmitters 307′ that are converted to electrical impulses and fed to network 302. This allows users to communicate with interface 300 by using the common infrared transmitters provided with many audio/video devices. The second capability allows interface 300 to regenerate stored control signals and to transmit them over network 302 to video transmitters 304a-304c. Those devices receive these signals and convert them to infrared light. As a result, processor 312 can control infrared responsive devices connected to network 302.

Control signals are detected and digitized within interface 300 by signal processor 330 (Fig. 16), and then passed over link 330′ to controller 316, as described above. Controller 316 stores these digital signals in its

digital memory, using known techniques. Interface 300 uses this detection, digitization, and storage procedure to "learn" to identify common consumer electronic control signals through a cyclical learning procedure. This procedure is now defined.

Referring to Fig. 18, controller 316 includes digital processor 380, digital memory 381, and buffer 382. Digital processor 380 connects to links 326′, 328′, 329′ to establish one-way communication to control various components of RF/video processor 312 according to procedures described elsewhere in this disclosure. Link 311′ establishes two-way communication with processor 311, and with detector 364 and modem 317 in particular. Link 320′ connects to processor 312 to provide two-way communication between controller 316 and keypad/display 320. That link also connects directly to message storage area 381a in digital memory 381. Digitized signals arriving over link 330′ from processor 330 are stored in buffer 382 that feeds storage area 381b of digital memory 381. It will be appreciated that controller 316 operates under programmed control, receiving signals through its various communication lines, and issuing signals in response. As such, master controller 316 can be programmed using well known means. One method is to program controller 316 via communication with keypad/display 320.

Processor 380 begins the cyclical learning procedure when a user enters a preset keystroke sequence on keypad/display 320. Then, in the first step of a learning cycle, the user delivers a first message to digital processor 380 through keypad/display 320. Processor 380 stores this message in storage area 381a.

In the second step of each cycle, controller 316 receives a digitized version of a control signal from processor 330, and associates it with the first message by storing it in a location of storage area 381b that

corresponds to the storage location in area 381a in which the first message has been stored. This is done in the following manner. A user directs light patterns from an infrared transmitter at one of video receivers 303a-303d, which detects that signal and spreads it across the wiring in electrical form using the techniques described in U.S. Patent No. 5,010,399 and Part I of this disclosure. (During the learning cycle, a video receiver can be located close to interface 300, so as to make this procedure easier for the user.) This control signal is received and digitized by processor 330 and passed to master controller 316 using the reception and digitizing procedure described earlier and shown in Fig. 16. The signal is stored in buffer 382. Processor 380 subsequently transfers that signal to the location in digital memory reserved for the first digitized control signal.

The succeeding cycle stores a message in the second location reserved for messages, and a digitized control signal in the associated location. The procedure continues to cycle through these two steps until, during the first step of a cycle, the user issues a message indicating the end of the learning mode.

After the learning cycle, controller 316 operates in normal mode. When in its normal operating mode, processor 330 digitizes each infrared signal it detects, and feeds it to buffer 382. Processor 380 then compares the digitized signal with signals previously stored. Processor 380 interprets a match as the communication of the message associated with the stored signal. Processor 380 can interpret the lack of a match as a "false alarm," and respond by returning to a quiescent state, waiting for the next detection of a digitized signal from processor 330.

Many types of one-way communication between the user and interface 300 are facilitated in this manner. Using the cyclical learning system very primitively, for example, each key of an infrared transmitter with 36 keys can be

associated with the 36 alphanumeric characters (26 letters and 10 numbers.) Thus, when the key of the transmitter that issues a signal that processor 380 "learned" to associate with the letter "z" is depressed while in "normal mode," the user of that transmitter will have communicated the letter "z" to controller 316.

The response of controller 316 to a message will be determined by the software in its memory (recorded in storage area 381c) that implements the "programmed control," and will be limited by the power that controller 316 can exercise over the elements of the system. As described earlier, the controller 316 can, among other things, instruct graphical processors 329a-329e to overlay any alphanumeric character on each of the signals sent onto network 302, and it can also control the signal selected and basebanded by modulators 326a-326e. As will be described below, controller 316 can also send control signals to infrared responsive video sources connected to video transmitters 304a-304c. Thus, the software of controller 316 can implement many different communication/control algorithms. An example will be described shortly.

An alternative to the cyclical learning system is to have processor 380 store a digital representation of the waveforms of control signals from a large number of common transmitters. A list of these signals can be provided in the documentation manual of interface 300. Then, using keypad/display 320, a user can "teach" processor 380 by issuing instructions to associate a particular message with a particular digitized signal. Then in normal operating mode, processor 380 operates as before, i.e. the match of a received control signal with a stored signal is interpreted as communication of the message associated with the stored signal, and the program in processor 380 reacts to that message.

Master controller 316 can also transmit control

signals onto network 302 to control infrared responsive components. This is done as follows. Using the iterative learning process described above, digital representations of control signals are stored in memory 381 of processor 316. Alternatively, these signals can also be stored at manufacturing time. In that case, the signals from many controllers should be stored at once. That would ensure that, in any arbitrary residence, controller 316 is likely to include all or most of the signals that are meaningful to the infrared responsive video devices connected to the network.

In response to a particular stimulus, the governing program of controller 316 transmits the digital representation of an analog waveform across communication link 330′ to control signal creation processor 338, shown in Fig. 16. Inside processor 338, standard digital to analog circuitry 360 recreates the basebanded analog waveform from the digital representation. The analog signal is then used by modulator 361 to modulate a carrier at an RF frequency. The preferred frequency of the carrier is the same one used for transmission of control signals by video receivers 303a-303d. This provides the economy that video transmitters 304a-304c need only be equipped to detect signals with a single carrier. The preferred band for this carrier is 72-76 MHz, as described above. The modulated signal is then amplified by amplifier 362. The modulation and amplification techniques and parameters necessary for transmission across the wiring are described in U.S. Patent No. 5,010,399 and Part I of this disclosure.

It will be appreciated that the frequency band used for control signals generated by circuitry 338 is the same as that used by control signals applied to demodulator 339 from network 302 (i.e., 72-76 MHz). To avoid the control signals produced by circuitry 338 "wrapping around" and being applied to controller 316 via demodulator 339, detector 338′ opens switch 339′ whenever control signals

are generated by circuitry 338.

After amplification, the signal is passed through bandpass filter 336, coupler 325, high pass filter 313 and onto network 302. The video transmitters 304a-304c connected to network 302 will detect these signals and use them to recreate the infrared patterns to which the certain signal sources respond. Note that, when the same carrier is used to modulate the control signals within both processor 312 and video receivers 303a-303d, filter 336 will be identical to filter 334. Two filters and two paths are shown in Fig. 16, however, to show the more general design that obtains when different carrier frequencies are used by processor 312 and the video receivers 303a-303d.

Following is an example of communication and control using the two new features described in this section. Assume that modulator 327b transmits its output AM encoded and between the frequencies of 6 and 12 Mhz, and that video receiver 303a is tuned detect AM video signals in the same 6 Mhz channel and to provide them to television 305a. A viewer watching television 305a uses an infrared transmitter whose command set has been "learned" by controller 316. Using signals "learned" by the software, this viewer communicates to controller 316 that VCR 307 should begin recording VHF channel 4 at 4 PM. Controller 316 "echoes" this message onto television 305a by instructing graphical processor 329b to overlay the alphanumeric characters "RECORD channel 4 at 4 PM" on the signal it outputs to modulator 327b. Finally, processor 380 transmits the "change to channel 4" signal and the "record" signal of VCR 307 to video transmitter 304b at 4 PM. Transmitter 304b responds by issuing that signal in infrared form to VCR 307.

As described, the power to detect infrared control signals, store them, and reissue them makes RF/video processor 312 a powerful device when operating under programmed control. Many possibilities are available to a

user that programs such a device. One possibility in particular appears to have interesting potential. That is the possibility that any single infrared transmitter can be given the power, via processor 312, to control all of the infrared responsive devices connected to the network. To provide this capability, controller 316 is first taught the command sets of the infrared responsive devices. This can be done using the learning cycle described earlier. Then, controller 316 is taught the commands of the infrared transmitter that is to receive enhanced capabilities. Finally, controller 316 can be programmed, via keypad/display 320, to associate signals from the enhanced transmitter with those of other devices.

Interactive Video Communication (Fig. 12)

Another important advantage of routing all video signals through a single RF/video processor 312 is that a single device, i.e. processor 312, can cause graphics and text to be overlaid on any of the video signals sent over network 302 to televisions 305a-305c. Using known processing techniques, digital information representing a graphical image of virtually any size, shape, and color can be combined with an unmodulated analog video signal, generating a picture in which the graphical image overlays the picture provided by the analog signal. Digital electronics can also, of course, provide a complete video signal, as interactive video games do.

Digitally encoded images are selectively added to the transmission system by graphical processors 329a-329e, which are interposed between video switch 328 and modulators 327a-327e, respectively. Each graphical processor 329a- 329e can receive a different digital representation of an image from controller 316 over communication link 329'. (Controller 316 generates this information using known techniques available to devices with programmable logic and digital memory. Any of the "input" stimuli provided to controller 316, such as control

signals from processor 330, signals from keypad 320, and DTMF signals from processor 311 can be programmed to cause controller 316 to take any particular action, including overlaying graphics.) Typically, this information will include text, such as a graphical image that indicates the identity of the channel from cable TV feed 315a that is being transmitted.

Graphics processors 329a-329e combine the graphical information from controller 316 with the unmodulated video signals transmitted by switch 328. The resulting signal, in which the graphics are overlaid on the video signal (i.e., the TV picture), is passed to the corresponding modulator 327a-327e. (Graphical processors 329a-329e can also, of course, pass the video signals from switch 328 without adding graphics.) Alternatively, the graphical image provided by controller 316 may fill the entire video screen, completely replacing the signal sent by switch 328.

The introduction of videotext, graphical overlays, and digitally created video signals allows controller 316 to communicate with the users in the residence. For example, any digital information stored in controller 316 can be displayed as text on the picture. Also, information downloaded from the public network by modem 317 and passed to controller 316 over link 317' can be displayed on any of the televisions connected to network 302. This information can be graphical in nature, allowing complete pictures to be sent over public network 301 and displayed on the televisions connected to network 302.

RF/video processor 312 can also deliver synthetic voice messages by replacing the sound component of video signals sent to the various televisions. The ability to deliver infrared control signals across the wiring to control the video and other components, as described above, is also a form of communication.

To provide communication in the opposite direction, (i.e. between the user at a remote location in the

residence and interface 300) either DTMF signals from any telephone on network 302 or control signals from infrared transmitters such as device 307' can be used. These communication paths are described above. Thus, a user can issue touch tone sequence "#*3", for example, to indicate "record." Processor 311 detects this sequence, and passes it to controller 316. If a matching command (stored in controller 316 during the above-described learning process) is found, controller 316 responds to the sequence by issuing an infrared signal that commands VCR 307 to begin recording.

As is clear from the above description, master controller 316 acts as the nerve center of the communications system. The DTMF, infrared, video, and modem communication paths allow for many novel applications. The communication paths and control functions are summarized below:

1) Controller 316 receives touch tone or DTMF signals from telephones on either the residential network 302 or public network 301 by connection to telephone signal processor 311.

2) Controller 316 receives and transmits digital information from outside the residence via modem 317 which connects to public network 301. This information is provided to controller 316 via communication link 311'.

3) Controller 330 receives all control signal information transmitted onto the residential network by the video receivers using means described in U.S. Patent No. 5,010,399 and Part I of this disclosure. It digitizes these signals and provides them to controller 316.

4) Controller 316 controls the video sources by transmitting control signals onto the network. These signals are detected by video transmitters 304a-304c, and used to recreate infrared patterns to which the video sources respond.

5) In response to the various control signals, controller 316 controls demodulators 326a-326e and switch 328 to select the signals to be distributed to the connected televisions.

6) Controller 316 directs graphical processors 329a-329e to overlay graphics on the video signals

distributed to the video receivers.

## Other Embodiments

Other embodiments are within the following claims. For example, one or more of the multiple signal processing and communication functions that have been assigned to the various components of interface 300 (Fig. 11) can be assigned to other components of the interface without changing the overall functionality of interface 300.

In addition, an alternative embodiment of selection and conversion processor 337 (Fig. 12) of RF/video processor 312 is described below.

## Alternative Distribution Systems (Fig. 19)

Selection and conversion subprocessor 337 of Fig. 12 includes a considerable amount of processing circuitry and provides many different functions. A converter box that includes a subprocessor with less circuitry and less functions, however, may be more attractive in some applications because it is less expensive. In particular, a converter box that simply provides multiple cable signals without retransmission and without graphical overlays can be very attractive as a retail item and also as a device provided by cable companies. Consumers may wish to purchase such a box to expand their cable TV distribution without buying an expensive or complicated device. Cable companies may prefer this box over others because they are content to limit their service to cable TV signals and leave graphical overlays and VCR and camera signal distribution to the consumer.

Fig. 18 shows selection and conversion subprocessor 370 for use in RF/video processor 312 in place of subprocessor 337. Electronically, subprocessor 370 is a subset of subprocessor 337. It is shown in this section because the inventors feel that it may be the most popular design for these types of devices, and because it provides an illustration of how the functionality of the video

distribution system can be changed by changing the selection and conversion subprocessor.

Cable TV signals are fed to subprocessor 370 through port 315. These signals are split three ways, feeding demodulators 371a-371c (demodulator 371b is shown in detail). Under control of master controller 316, each of demodulators 371a-371c demodulates (and descrambles, if necessary), one of the cable signals. Controller 316 exercises control over demodulators 371a-371c (e.g., tunes the local oscillators within demodulators 371a-371c so that the selected cable TV channels are demodulated) by passing signals over communication links 371'. Because the cable TV signals are AM, conventional envelope detection and filtering is employed by each demodulator after the incoming signal is downconverted.

The basebanded signals produced by demodulators 371a-371c are passed to modulators 372a-372c, respectively. Details of modulator 372b are shown. It will be appreciated that each modulator 372a-372c includes a mixer, a fixed frequency local oscillator (the local oscillator frequencies are all different) and a filter to remove, e.g., the lower sideband produced by the mixer. Modulators 372a-372c thus convert the applied signals to the frequency bands and waveforms (i.e., AM, although by modifying the modulators FM may alternatively be used) at which they will be transmitted across telephone wiring 302. The outputs of modulators 372a-372c are combined by coupler 331 and fed to amplifier 332. After amplification to the level at which they will be broadcast across network 302, the three combined signals are fed through bandpass filter 333 and onto the network. The functions of filter 333 are described above.

Various considerations for the choice of frequency band, waveform, and energy level are also discussed elsewhere in this application and in U.S. Patent No. 5,010,399 and Part I of this disclosure. A preferred

method of reception is for each video receiver 303a-303d to receive only a single signal within a (channel) frequency band that is determined by a manual setting. A preferred method of channel selection is for subprocessor 370 to determine the signal received by such a video receiver by determining the signal demodulated by the one of demodulators 371 whose output is transmitted over that particular channel.

Using a Second Twisted Pair to Transmit Additional Signals

As discussed above, the number of signals that can transmit over network 302 is limited by the increasing attenuation of energy at the higher frequencies. In most residences, however, the telephone wiring consists of several twisted pairs. Each of these pairs typically branches off to connect to each of the jacks in the residence. One of these pairs, typically the one whose conductors are colored red and green, conducts the signals for the primary telephone service to that unit. Additional pairs are left empty unless and until secondary telephone lines are requested. (The conductors of the second pair are typically colored yellow and black.)

Ordinarily, crossover of energy from one pair to another can create interference, preventing use of these extra wires for transmitting additional signals within the same channels. Part I of this disclosure, however, describes how encoding video signals using frequency modulation can be sufficient to prevent crosstalk interference between two pairs that serve the same unit, thereby preserving the opportunity for transmission of additional signals. Thus, the channels used for FM communication in this application can be used to transmit different signals on different pairs simultaneously, thereby increasing the capacity of the system.

Part I of this disclosure describes the phenomenon of "nearend" crosstalk, however, that requires that signals using the same FM channel on neighboring twisted pairs in

a bundle to originate at the same point on the wiring network. Thus, the extensions proposed in this section are confined to transmission of FM signals from processor 312.

To adapt processor 312 to use extra pairs, some of modulators 327 can simply connect to transmission paths feeding the second pair. For example, referring to Fig. 12, let modulators 327a and 327b both transmit their signals using the 108-120 Mhz channel of range 340c. To prevent interference, modulator 327a is connected to coupler 331a (not shown) rather than coupler 331. Signals fed to coupler 331a pass through amp 332a, filter 333a, coupler 325a, and filter 313a. These components, which are not shown, are companions to coupler 331, amp 332, filter 333, coupler 325, and filter 313. They are identical (except for coupler 325a) to their companions, and are connected in the same way. Coupler 325a is different because it need only include two ports: the one receiving video signals from filter 333a and the one transmitting video signals through filter 313a. Filter 313a connects to the second pair instead of the pair to which filter 313 connects.

**Part III - Two-Way RF Communication at Points of Convergence of Wire Pairs from Separate Internal Telephone Networks**

A. Overview (Fig. 21a)

Referring to Fig. 21a, the technology described in this application is designed to communicate signals between transceiver/switch 400, located where individual telephone lines from multiple local networks converge for connection to a main telephone trunk 476', and groups of RF communication devices that are connected to the individual local networks 411a-411e of telephone wiring. Each of local networks 411a-411e (collectively "local networks 411") includes the wiring confined to a structure such as a house or to an area within a structure such as an apartment unit or a room in an office building. This wiring provides a single conductive path for a single

ordinary telephone signal. Thus, in the case of the common four conductor telephone wiring, the red/green pair constitutes one local network, and the yellow/black pair constitutes a second local network. (The only special relationship between these local networks is that they bundle more tightly together than wiring serving different areas. Theoretically, this could increase the crosstalk between the pairs.)

Note that the details of the wiring of local networks 411d, 411e are not shown in Fig. 21a. Those local networks will not be served by the communication system described herein. They are included only to demonstrate that not all local networks within a group whose wires converge at a particular point need participate in the communication system described herein.

The wiring of each local network further includes a single branch that strays far from the structure, ultimately leading to the point of convergence where they connect to (or become part of) trunk 476'. These are extended pairs 405a-405e, (collectively, extended pairs 405.) The extended pairs 405 from each of local networks 411 may be bundled closely together near the point of convergence.

When transceiver/switch 400 is installed, extended pairs 405 are broken near the point of convergence, with transceiver/switch 400 interposing between the two ends of each pair. One segment of each pair remains connected to trunk 476'. These segments are called twisted pairs 476a-476e, (collectively, twisted pairs 476.) Thus, twisted pairs 476 and their associated extended pairs 405 ordinarily constitute an uninterrupted connection between local networks 411 and local telephone exchange 475. In the system described herein, transceiver/switch 400 interposes between these wires to provide a link between communication line 402 and local networks 411. As will be described below, one of local network interfaces 404a-404c

may also interpose along this path, in the middle of or at the opposite end of the corresponding one of extended pairs 405.

Communication line 402 provides high capacity communication (such as for cable TV signals) with remote locations. Line 402 includes one or more coaxial cables, optical fibers, or the like. Transceiver/switch 400 connects to line 402 to receive and transmit signals. It processes the signals it receives, and switches them onto selected ones of extended wire pairs 405 leading to local networks 411, together with (and without interfering with) the telephone signals (e.g., voice signals) that also use those wires. The switched signals are received by the RF communication devices connected to local networks 411.

Transceiver/switch 400 also receives video, digital, control, and other types of signals from extended pairs 405. These signals, which normally originate in the areas served by the local networks 411, are applied to local networks 411 by the connected RF communication devices, and transmit across extended pairs 405 to transceiver/switch 400.

Local network interfaces 404a-404c (collectively, interfaces 404) are respectively interposed on extended pairs 405a-405c, thus connecting between transceiver/switch 400 and the corresponding local networks 411. Typically, they will be located at a part of extended pairs 405 that is closer to the corresponding local network 411, rather than transceiver/switch 400. They assist in the transmission of signals in both directions between transceiver/switch 400 and local networks 411, as described in more detail below.

Each local network interface 404 intercepts signals sent from the corresponding extended pair 405, applies amplification and/or other signal processing, and feeds the resulting signal onto the corresponding one of local

networks 411. This assists in the transmission between transceiver/switch 400 and local networks 411. Each local network interface 404 also performs a similar function to assist signals that are transmitted in the other direction, i.e., by receiving signals from one of local networks 411 for transmission to transceiver/switch 400 via one of extended pairs 405.

As is emphasized at several points in this document, local network interfaces 404 need not be used in some conditions, particularly when extended pairs 405 are relatively short, e.g., less than 300 feet in length. Such is often the case in apartment buildings. This is fortuitous because there is often no opportunity to interpose a device between the point of convergence and the telephone jacks in an apartment unit when a transceiver/switch is located in the wiring closet on each floor of the building. (When the point of convergence is a room in the basement where all the twisted pairs converge, the wiring closets are good locations for local network interfaces, as is described in greater detail below. A communication system is shown in Fig. 21b and described later on that does not include local interfaces 404.)

The communication devices connected to local networks 411 are now described. Video receivers 419a-419c and 419a', video transmitters 417b-417c, digital transceiver 491c, and telephone devices 414a-414c (collectively, telephone devices 414) all connect to local networks 411a-411c as shown in Fig 1a. Except for telephone devices 414, all of these devices communicate RF signals over local networks 411, and are referred to herein as RF transmitters and RF receivers. The RF signals they apply to local networks 411 are received by local network interfaces 404 and retransmitted across extended pairs 405. (These signals can also be received by other devices

connected to local networks 411.) Any number of RF transmitters and receivers and telephone devices can connect to any one of local networks 411.

Each of telephone devices 414 connects via a low-pass filter (LPF). As described in Part I of this disclosure, these filters prevent telephone devices 414 from affecting RF energy on the local networks 411. These filters may be provided as part of splitter 161, which is described in Part I of this disclosure.

The video transmitters and receivers are those described in U.S. Patent No. 5,010,399 and in Parts I and II of this disclosure. Video receivers 419a-419c and 419a' (collectively, video receivers 419) connect to televisions 492a-492c and VCR 498a, respectively. Video receivers 419 also detect infrared (IR) light signals, convert them to equivalent electrical signals, and apply them to the corresponding one of local networks 411. These signals transmit across extended pairs 405 to transceiver/switch 400 for purposes described in detail below. Infrared transmitters 493a-493c (collectively, infrared transmitters 493), are respectively provided at local networks 411a-411c to produce the IR signals.

Video transmitter 417b connects to video camera 494b. It derives a video signal from that device, processes the signal, and applies it to network 411b. Camera 494c connects to video transmitter 417c which connects to local network 411c and operates in a similar manner. Transmitters 417b and 417c also receive the control signals applied to their associated local network 411. They convert these signals to infrared signals equivalent to the original signal, then broadcast them out into the vicinity for reception by nearby infrared responsive devices.

Digital transceiver 491c connects between a computer 495c and local network 411c. It receives digital signals

from the network wiring and transmits them to computer 495c, and it also receives signals from computer 495c and applies them to the wiring. Digital transmitters and receivers are described in Part I of this disclosure. That application also describes how to combine RF transmitters and receivers into a single device that communicates through a single connection to active telephone wiring.

Except for control signals meant to communicate with transceiver/switch 400, the non-telephone signals received from extended pairs 405 by transceiver/switch 400 are fed to line 402 for transmission to other communication devices that connect to line 402 at locations removed from transceiver/switch 400. One application for this is to establish a simple two-way videoconference between two people located near opposite ends of communication line 402 or at two points of line 402 that are far from each other.

In the reverse direction, transceiver/switch 400 can transmit any of the signals (such as cable TV signals) selected and recovered from communication line 402 over any one of the extended pairs 405, without disturbing the telephone signals that also use those wires. A single selected signal (e.g. an ordinary NTSC television signal) can be assigned to more than one pair, and several signals can be assigned to the same pair.

The processing performed by transceiver/switch 400 on the signals it recovers from communication line 402 converts those signals to the waveform (e.g. the modulation type such as AM or FM) energy level, and frequency band at which they will be effectively transmitted onto wire pairs 405. These signal characteristics must be such that the signals will communicate with high fidelity over extended pairs 405a-405c to the RF communication devices connected to local networks 411a-411c. The relationship between these signal characteristics and the success of this communication is discussed at length below.

The selection of the signals from line 402 and their assignment to particular ones of extended pairs 405a-405c (and thus their assignment to the various local networks 411a-411c) is made by transceiver/switch 400 in response to the control signals sent from local networks 411 over extended pairs 405. Transceiver/switch 400 also receives and responds to control signals from communication line 402, which can give the originator of those signals partial control over signal distribution to local networks 411.

The signals from local networks 411 to which transceiver/switch 400 responds in making selections are known as "control" signals and are sent by subscribers using infrared transmitters 493. Using techniques partly described in U.S. Patent No. 5,010,399 and Parts I and II of this disclosure, video receivers 419 detect these infrared signals, convert them to electrical signals and apply them to local networks 411. These signals then transmit to transceiver/switch 400, as is described below. Control signals from local networks 411 can also be generated by other means, and applied to local networks 411 by other RF communication devices. The digital transmitters described in Part I of this disclosure, for example, can respond to manual inputs to transmit an electrical signal(representing binary information) onto local networks 411. This electrical signal can be used to communicate a channel selection to transceiver/switch 400.

Following is an example of how this system is used to communicate video and control signals. First, assume communication line 402 conveys 30 video signals from a local cable TV franchise. According to the invention, transceiver/switch 400 selects one or more (typically one or two) video signals from among those 30 to be sent to, for example, local network 411a. Transceiver/switch 400 transmits the selected video signals over extended pair 405a to local network interface 404a. Interface 404a

receives these signals and retransmit them onto local network 411a, where they will transmit to video receivers 419a and 419a' and be provided to TV 492a and VCR 498a. Other RF receivers that connect to local network 411a can also receive these signals.

Viewers of television 492a connected to local network 411a via video receiver 419a, meanwhile, can use transmitter 493a to issue infrared control signals to determine which signals are selected and transmitted to local network 411a. Video receiver 419a detects these infrared patterns, converts them to electrical signals, and applies them to local network 411a. These electrical signals are received by local network interface 404a which processes them and relays the signal across extended pair 405a to transceiver/switch 400. These signals indicate to master controller 415 (Fig. 22) the identity of the cable TV signals that are to be sent to local network 411a. Alternatively, signals from communication line 402 detected by master controller 415 can also determine the identity of the cable signal to be sent to local network 411a.

The viewer can also transmit video signals from a local network 411 to communication line 402. This can be useful for any number of purposes, the most simple of which is to add pictures to an ordinary two-way telephone conversation. An example of this is where the signal from video camera 494b is applied to local network 411b by video transmitter 417b. That signal will transmit over local network 411b to local network interface 404b. Local network interface 404b receives the video signal and transmits it across extended pair 405b to transceiver/switch 400 which will apply the signal to communication line 402. (Again, local network interface 404b will facilitate this communication only if it is included in the system.)

There can be a large variation in the lengths of

extended pairs 405. In an apartment building, the telephone wires serving different units may converge at a point 100 feet or less from each apartment unit. An example of the other extreme occurs when distributing signals to separate houses in a neighborhood. In this case, connecting ten houses to the a single transceiver/switch 400 may mean that some of extended pairs 405 will be longer than, perhaps, 1000 feet.

Unfortunately, attenuation of the video signals increases with frequency, which means that the highest useful frequency on extended pairs 405 decreases with length, ultimately restricting the signals to below 4 Mhz. This is a problem because 4 Mhz of bandwidth is the approximate minimum required for transmission of an NTSC video signal in analog form. The inventors estimate that this point occurs before the lengths of extended pairs 405 reach 3000 feet.

The solutions described herein take advantage of the improved ability of RF (radio frequency) signals to transmit over longer distances at lower frequencies to avoid problems due to the lengths of extended pairs 405. The invention also takes advantage of the property of conducted RF transmission that dictates that the tendency for energy from a signal on one wire pair to cross over to a neighboring pair decreases as the frequency of the signal decreases. This crossover, which can cause interference, is likely to result when pairs 405 are closely bundled within a common sheath, as often happens. Finally, the ability of frequency modulated (FM) signals to resist interference to a greater degree than amplitude modulated (AM) signals with more narrow bandwidths also plays a part in the system design.

The next part of the disclosure describes the signal flow between major components internal to transceiver/switch 400, and the processing performed by